24 Is not animal motion performed by the vibrations of the medium excited in the brain by the power of the will?

We turn now to the last group of 7 queries

25.) Deals with double refraction -
Are there not other ~~properties~~ original properties of light besides those already described?

26) Have not the rays of light several sides?

27. Are not all hypotheses erroneous which explain properties of light by modifications of the rays - (reference to Hooke)

28 Are not all hypotheses erroneous in which light is supposed to consist in pression or motion propagated thro' a fluid medium

a) rectilinear propagation not explained

b) cannot explain polarization phenomena

c) cannot explain Fits of easy reflexion, easy transmission.

(later of course all this was explained by Fresnel with wave theory of light.)

N. is attacking Huygens, Treatise on Light (1690)
(Traité de la lumière)

p.369 N. proceeds to <u>attack</u> the idea of a medium, argues for existence of God — 'famous passage'

e.g. 'The main business of natural philosophy is to argue from phenomena without feigning hypotheses, and to deduce causes from effects' till we come to the very first cause, which certainly is <u>not mechanical</u>" ...

29 Are not the rays of light very small bodies emitted from shining substances?

31. Have not the small particles of bodies certain Powers, virtues or Forces by which <u>they act at a distance</u> not only upon the Rays <u>of light</u>, but also upon one another for producing a great part of the Phaenomena of Nature

This famous final query really outlines an atomic theory of matter and interatomic force — very influential in 18th C development in chemical elements and later in Laplacian field of theoretical ~~physics~~ physics dealing with elasticity, capillarity etc.

Also influenced 'electrical and magnetic theories of action-at-distance

p. 400

"All these things being considered it seems probable to me that God in the beginning formed Matter in Solid, Massy, hard, impenetrable, moveable particles of such sizes & figures, & with such other properties, and in such proportion to space, as most conduced to the End for which he formed them.

— — —

These particles are moved by certain Active Principles, such as is that of Gravity — —

These Principles I consider not as occult Qualities . . . but as general Laws of Nature . . . their truth appearing to us by Phenomena though their Causes be not yet discovered".

p. 402 Inconsiderable irregularities may arise" from mutual actions of comets & planets and which will be apt to increase, till this System want a reformation".

— Arg. for continued intervention of God in his universe.

Cf problem of stability of the solar system —

p. 404 God, could ~~not~~ 'say the word of Nature' and make water of several parts of the Universe. At best, I see nothing of contradiction in all this".

Concludes with analogy of compounds melted of analysis (per ~~Compounds~~ to ingredients) and then synthesis to explain phenomena proceeding from the analysis.

History of Science II

The course is centred round the history of Mathematics and Physics in the 19th Century.

Mathematics → Donald.

Physics discussed, three principal themes will be Energy, Atom and Field

these will lead to a study of the development of thermodynamics, the kinetic theory of gases, the theory of the electromagnetic field. The main emphasis will be on the period 1820 – 1870.

Relevant primary source material is separated in the following:

S. Brush: Kinetic Theory 1, The Nature of Gases and Heat

F. Mendoza (ed.): Reflections on the Motive Power of Fire

T.A. Hirst (ed): The Mechanical Theory of Heat (Clausius, Rankine)

J. Tyndall and W. Francis (eds.): Scientific Memoirs, Natural Philosophy

J.C. Maxwell: Scientific papers.

M. Faraday: Experimental Researches in Electricity.

Lord Kelvin: Mathematical and Physical Papers.

J.P. Joule: Scientific Papers.

W.F. Magie: A Source Book in Physics.

R. Lindsay (ed.): Energy: Historical Development of the Concept.

R. Leadsay (ed.): Early Concepts of Energy in Atomic Physics.

Background Reading.

D. Cardwell: From Watt to Clausius: The Rise of Thermodynamics in the Early Industrial Age.

C. Gillispie: The Edge of Objectivity, Chapters 9 and 10.

M. Hesse: Forces and Fields.

L. Pearce Williams: The Origins of Field Theory.

W. Berkson: Fields of Force.

S. Brush: The Kind of Motion we Call Heat (Volumes 1 & 2)

See also
T. Rubin: Energy Conservation as an Example of Sensitive Issues (1959)
(reviewed in The Essential Tension 1977)

Y. Elkana : The Discovery of the Conservation of Energy

C. Everitt : James Clerk Maxwell: Physicist and Natural Philosopher.

L. Königsberger : H. von. Helmholtz.

S.P. Thompson : Life of Lord Kelvin

J. Tyndall : Faraday as a Discoverer

L. Pearce Williams : Michael Faraday. A Biography.

F.T. Whittaker : History of the Theories of Aether and Electricity.

T. Schaffner : Nineteenth-Century Aether Theories.

J. Kestin (ed) The 2nd Law of Thermodynamics

R. Tricker . The Contribution of Faraday and Maxwell to Electrical Science

History II

2 views on 19th c. physics
1) Culmination of Newtonian mechanical world view

2.) Retreat from Newtonianism

We distinguish 3 components in Newtonianism

a) material substances (corpuscles)
b) motions of corpuscles
c) Forces between corpuscles - at a distance

Contrast Cartesianism

a) Material substance (continuum with particles as different states of aggregation of the continuum)

b) motion

c) 'contact' forces only.

Cartesianism leads to effluvial theories of electrical interaction (but these were thought of as streams of particles)
But contrast late 18th C imponderables electric, magnetic, caloric and optical fluids' which are regarded as corpuscular in nature (following Newton Boyle etc — cf Gassendi's revival of atomism of Democritus, Leucippus, Epicurus etc)

cp Abbé Nollet; LeSage Theory of gravitation

these Imponderable particles acted on one another at a distance as did the Corpuscles of ponderable matter.
This was the general view of the French Molecular school who explained continuum mechanics (Euler & Bernoulli) and Capillarity in terms of forces between corpuscles.

Main exponents of this school are Laplace, Poisson, Navier, Cauchy, St Venant, & Ampère.
Contrast the positivist phenomenological school of French Mathematical physics represented by Fourier

True continuum view held by Stokes in England and Helmholtz in Germany. Helmholtz contrasts two aspects of reality corpuscles & continua — waves & particles as we might say.

Several themes emerge in 19thC physics

1) Corpuscular theory of light → (Continuum) Wave theory light
2.) Caloric (continuum) theory of heat → Kinetic theory of heat.
 ↳ Conservation of Energy → Thermodynamics
3.) Action-at-distance in electromagnetism replaced by continuum field view of interaction
4.) Several views about fields
 a) Faraday — field = lines of Force
 Matter developes up Boscovich point atoms

2) <u>Maxwell</u> reconsiders mechanical views of ether, but regards it probably as ultimately corpuscular in Nature itself.

cf <u>Atmospheric Atoms</u> around 1800

material corpuscles surrounded by several atmospheres of imponderable particulate fluids and designed to explain electric, magnetic effects, thermal or gravitational effects.

Maxwell essentially reduced the imponderable fluids to ~~one~~ the electromagnetic aether ~~that~~ the ~~difficulties in this~~ concept → <u>Relativity</u>

N.B. The aether is all-pervading, unlike caloric or electric fluid.

<u>Note</u> Lavoisier abolished phlogiston — 'chemical' substance <u>emitted</u> in combustion, but strongly advocated the <u>caloric</u> theory of heat.

Three main concepts emerge

<u>Atom</u> — Dalton — chemical atom, 1808 'New System of Chemical Philosophy'

→ K.T. gases (not accepted by chemists until Cannizzaro revival of Avogadro (1811) in ~~18~~58.)

~~Kinetic Theory~~

Energy — Naturphilosophie, Schelling, Goethe, Coleridge

↳ All forms interconvertible

or all energy is at base mechanical
i.e. Kinetic, Potential.

Joint Discovery: Kuhn in Re. Essential Tension.

{Mayer 1842-45
Helmholtz 1847
Joule 1849

↳ ~~Field~~ ~~Faraday~~, ~~Maxwell~~.

Thermodynamics Practical & Lost

Energy for work — steam engine - Watt.

— Sadi Carnot (1824) — Reflections on the Motive Power of Heat —

↓
{Clapeyron
Clausius
Kelvin

Field Faraday ← Oersted (1820
Maxwell. At Ampère

↓
Action at a distance

↓
Weber
Franz. Neumann.

~~Reaction~~

e.m. theory of light (~~1861~~)
(1861)

Josef Loschmidt in 1865 estimated size of molecules.

mean free path from viscosity → Nd^2
No of liquid phase. → Nd^3

Hence we can estimate N and d

2×10^{18} (modern value is 2.7×10^{19})

10×10^{-8} cm for 1 air molecule.

d = diam. of molecule
N = no of molecules per cc. at STP
= Loschmidt's No

(cf Avogadro's No = no of molecules per gm molecule.)

K.T. gases — Newton – static Model (Principia) 1/r law

1.) Bernoulli 1738

2.) John Herapath 1820.

3.) Waterston rejected by R.S. 1845. later rediscovered by Rayleigh 1892.

4.) Joule. Calculated speed of molecules. ~~1847~~. (after Herapath) 1848
6225 f.p.s., 60°C, 30 in. Hg.

5.) Kronig 1856

6.) Clausius 1857 'on the kind of motion we call heat'.
1858 – mean free path.

7.) Maxwell. statistical methods (~~1860~~) 1859 and (1866)

8.) Boltzmann H theorem etc, 1868, 1872. 1860 & 1867

SH Novel prediction viscosity gas independent of pressure.

Difficulties Specific heats of gases and exact treatment of transport phenomena. – action not particularly aimed contributing to SH/S – two plus of continuous action – of Rayleigh–Jeans B.B. law.
Vortex Atoms model of ~~Thompson~~ Thomson (Kelvin)

Specific heats vary with temperature. Internal motions should only be handled by QM, internal degrees of freedom become unfrozen only at high temperatures.

Personalities

John Herapath (1790–1868)

1820 paper rejected by Royal Society
Equilibrium corresponds to equality of mv not mv^2
published in Annals of Philosophy, later in Phil Mag. — influenced Joule.
1847 published 2-volume Treatise 'Mathematical Physics' extending his 1820 work.

John Waterston (1811–1883)

1845 paper rejected by R-S "The paper is nothing but nonsense, unfit even for reading before the Society" rediscovered in Archives of R.S. by Rayleigh in 1891, reprinted with Rayleigh's comments — get $n_1 v_1^2 = n_2 v_2^2$ law of equilibrium.

James Prescott Joule (1818–1889) 1857 paper in Phil. Mag. was originally published in 1848 in Memoirs of the Manchester Literary and Philosophical Society. See also his lecture 'On Matter, Living Force and Heat' in Manchester Courier 1847

August Krönig (1822–1879) . 1856

paper. 1st revival of K.T. after 1st law of thermodynamics had been established.

Rudolf Clausius (1822–1888) real founder of K.T. 1857 'On the Kind of Motion we call Heat' — developed from his

ideas of thermodynamics
— Helmholtz, Clausius, 1850's
revival of kinetic theory of gases (1858)

1858 calculated concept of mean free path.

James Clerk Maxwell (1831–1879)

of Adams Prize Essay on Saturn's rings

1860 ~~1859~~ paper develops theory of transport phenomena, in particular viscosity η

η independent of pressure & $\propto \sqrt{T}$.
Experiment showed $\eta \propto T$ — postulated $1/r^5$ force law in his 1867 paper

Maxwell also introduced distribution & velocities among molecules in a gas

Radiometer paper sent before his death in 1879.

Ludwig Boltzmann (1844–1906)

extended Maxwell's analysis to derive the general non-equilibrium situation in a gas — the Boltzmann Eq. & H theorem derived in 1872 —

Reversibility, Recurrence paradoxes
~~Loschmidt~~ Loschmidt ↑ (1874?) — Zermelo ↑ (1896)

J.D. <u>Van der Waals</u> (1837– 1923)

developed theory of non-ideal gases
$(P + a/v^2)(V - b) = RT$ in 1873
demonstrated continuity of gas & liquid states – analysis of critical phenomena

cf <u>Andrews</u> CO_2 isotherms (1863)

and <u>James Thomson</u> (Kelvin's brother) suggested <u>continuity of state</u> in 1871

<u>Ernst Mach</u> (1838–1916)

opposed K.T. in 1872 onwards.

Open debate between Ostwald and Boltzmann in 1895

cf J.T. Blackmore's book 'Ernst Mach'. (1972).

Mach said also in 1903 he reported he once said 'Now I believe in the existence of atoms!' (Spinthariscope demonstrating α-particle scintillations) – seeing may be believing?

NB. Dewar & Rolleri theory of heat
due partly to ideal
radiant heat = light = wave motion
(not a substance)

∴ heat not a substance

NB Fireless or a Leslie Cube can
produce only radiant current
of heat

Vis Viva

mv^2 conserved in ^elastic^ collisions shown by C. Huygens (1629–1695) in 1703
(De Motu Corporum ex Percussione)

mv^2 given the name vis viva by
Leibniz in 1695 — contrast with
Vis Mortua — K.F.

Leibniz subscribed to a doctrine of general conservation of vis-viva
P.E. is vis. viva of the atoms
— theory rather unclear.

Concept of Energy

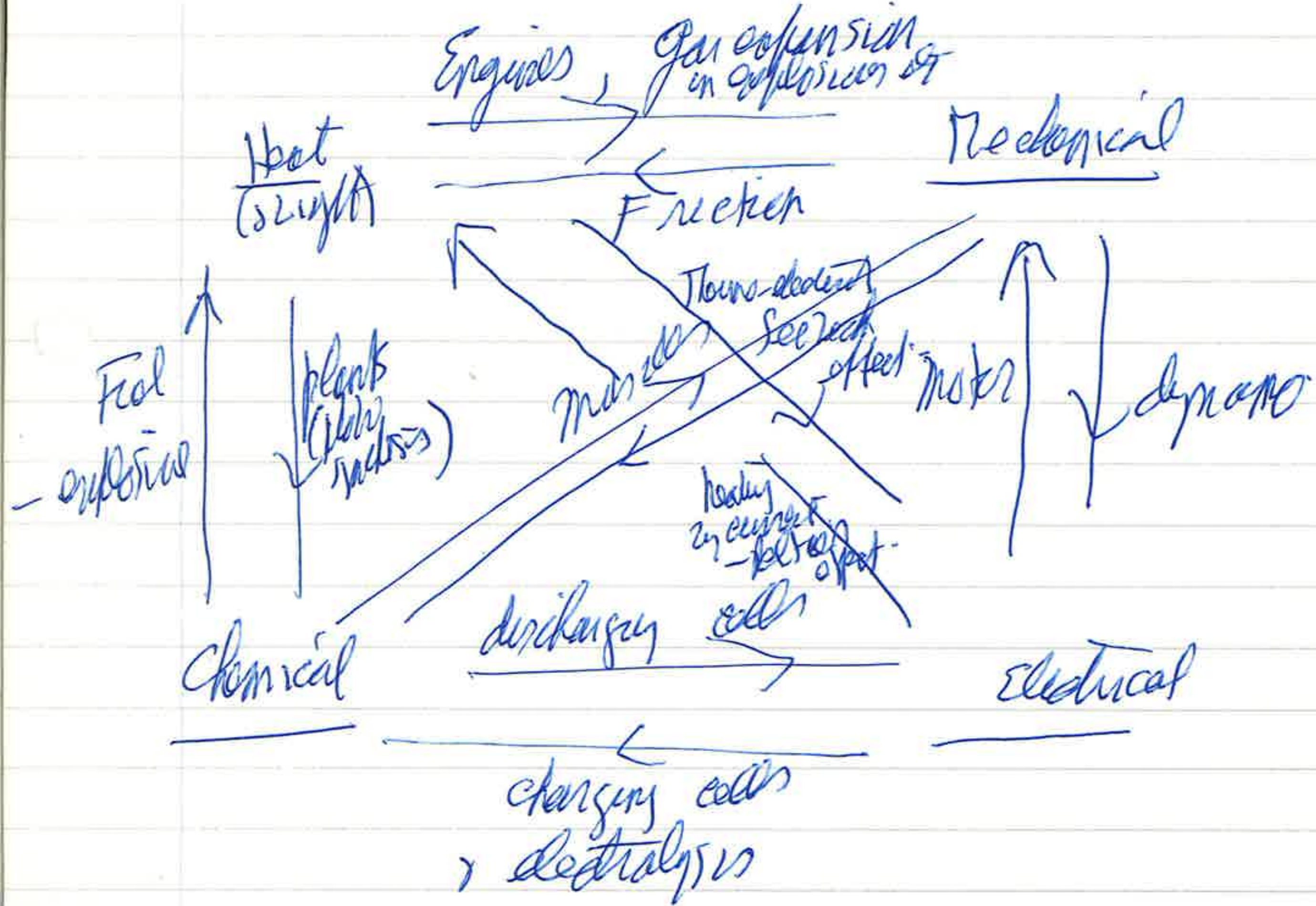
Conservation of Energy — cf. Kuhn's Essential Tension p 66 Energy Conservation as an Example of Simultaneous Discovery

Mayer, Joule, Colding, Helmholtz Clausius (1842–1847)

[illegible]

3 Approaches

1.) Conversion Processes



2.) Concern with engines - Development of the steam engine

3.) Nature Philosophie

Limited conversions heat, work Holtzmann (1845)
Carnot (1824 1832) Séguin 1839, Hirn, 1854.

1837–1844 Vague qualitative notion of a 'single' force differently manifested
Mohr, Grove, Liebig and Faraday

Julius Robert Mayer (1814 – 1878)

Physician, a Kantian, ship's surgeon in tropics – 'venous blood redder in the tropics', less oxygen being used

oxygen = work + heat loss
| less in tropics

concerned with transformation of vital and inorganic forces, main papers 1842, 1845

– Calculated mechanical equivalent of heat from $c_p - c_v = R/J$
(gas constant)

James Prescott Joule (1818 – 1889)

1843 announces equivalence of heat, work and electrical mechanism

1845 paddle wheel expt. – direct conversion mechanical → heat

1847 general statement in Manchester 'Courier' 'On Matter, Living Force and Heat'.

Hermann von Helmholtz (1821 – 1894) (also trained as a physician)

1847 Erhaltung der Kraft – all energy is ultimately mechanical – conservation of energy for system of particles under central forces

Jean Baptiste

N. B. Joseph Fourier (1758-1830) published
his Analytical Theory of Heat
in 1822.

History of the Steam Engine

1691 Denis Papin suggested caloric
steam as model of ideal
of the atmospheric process

1699 Thomas Savery first working
engine on Papin's principle

1712 (maybe 1705?) Thomas Newcomen,
first practical engine for pumping
water out of mines (de Caus)
John Smeaton improved in detail

James Watt (1738-1819) introduced separate
Condenser (patented in 1769 - invented
in 1765)

Developed by Woolf, Trevithick
Stephenson etc - steam tractor

History of Thermodynamics

Main problem here is availability of energy

Sadi Carnot (1796–1831) 'Reflexions on the Motive Power of Fire' 1824 explained Carnot Cycle.
Showed no heat engine could be more efficient than a reversible one – a perpetual motion
Efficiency depends only on Temperature drop available
Assumes Caloric theory of heat.
ie $\frac{\Delta W}{Q} = \frac{T_1 - T_2}{C}$ — Carnot function.

Emile Clapeyron (1799–1864) good mathematical exposition to Carnot's ideas, derived his latent heat equation in 1834

Carnot's work rediscovered & promoted by William Thomson, Lord Kelvin (1824–1907)
(He was second wrangler, published several papers, 17 awards / also like Maxwell)

In 1848 proposes absolute thermodynamic scale but still uses Caloric theory. $\frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$

Develops dynamical theory of heat in 1851 'On the Dynamical Theory of Heat', [illegible]

* Kelvin's version of 2nd Law

Work cannot be performed by cooling a reservoir below the temperature of its surroundings

N.B. Rankine developed a version of the 2nd Law in 1850

† Clausius version of 2nd Law

Heat cannot flow spontaneously from a cold body to a hot body

his version of the 2nd Law:*

1854 applies 2nd law to thermoelectric Seebeck, Peltier & Thomson effects - shows $\oint_{rev} \frac{dQ}{T} = 0$

Also c. 1849 predicts lowering of freezing point of water by pressure. (with his brother James Thomson).

Rudolf Clausius (1822 – 1888)

enunciates 2nd Law. in 1850

'On the Moving force of heat and the laws regarding the Nature of Heat', adopts the dynamical theory of heat. Carnot's theorem derived as corollary 2nd Law+, not as perpetual motion (cf. 1st Law).

1865 9th memoir Entropy Law

$\int \frac{dQ}{dT} \geq 0$

N.B. term Entropy first coined by Clausius in 1854

Ludwig (1844–1906)

Nernst Boltzmann's noted equation

$S = k \ln W$ in 1877

↓ ↓

Entropy thermodynamic probability

N.B. Thomson in 1852 published his paper 'On a Universal Tendency in Nature to the Dissipation of Mechanical Energy' — cf. Clausius' increase in entropy.

The new view of Nature is not of reversible clockwork but of the gradual running down of an irreversible approach to heat death of the universe.

Tension between irreversibility of thermodynamics and reversibility of dynamical theory resolved (in part) by statistical arguments of Boltzmann.

Note $\frac{Q_1 - Q_2}{Q_1} < \frac{T_1 - T_2}{T_1}$

$\Rightarrow 1 - \frac{Q_2}{Q_1} < 1 - \frac{T_2}{T_1}$

or $\frac{Q_2}{Q_1} > \frac{T_2}{T_1}$ or $\frac{Q_2}{T_2} - \frac{Q_1}{T_1} > 0$

or $\frac{Q_1}{T_1} - \frac{Q_2}{T_2} \leq 0$ for an irreversible change

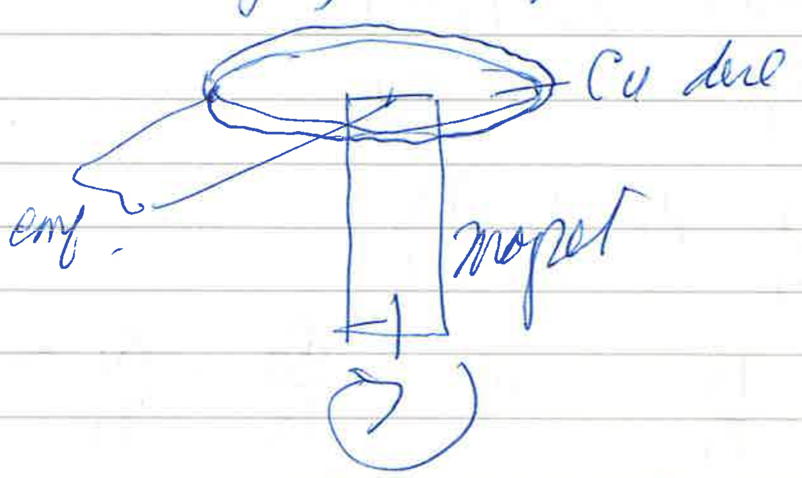
$S_1 - S_2 \leq 0$

or $S_2 \geq S_1$

Vol I, p.16

At first Faraday thought magnetic field produces electrotonic state in wire (identified by Maxwell with the vector potential) — changing field produces change in the electrotonic state which we interpret as current.

I, p.124 But phenomenon of unipolar induction suggested to Faraday a model in terms of cutting lines of field rather
I, p.66 than changes to field-electrotonic state.



cf I, p.16 Faraday also thought electrotonic state involved in electrostatic induction
'Whilst the wire is subject to either volta-electric or magneto-electric induction, it appears to be in a peculiar state'.

19th Century Field Theory

1. Wave Theory of light developed by
Thomas Young (1773-1829) (in 1801)
and Augustin Jean Fresnel (1788-1827) who
developed mathematical theory of diffraction
in 1818 (& of double refraction in crystal; light is a transverse wave (1821))

Prediction of 'bright spot' by Poisson in 1818.
(defeat of Fresnel's Prize Competition examiners) — demonstrated by Fresnel — prime example of a novel prediction.

↳ Slowness-speed theories of the
Luminiferous ether

2. Faraday and Electromagnetism

Michael Faraday (1791-1867) Assistant to
Davy at the R.I. Succeeded him as
director.

Hans Christian Oersted (1777-1851) discovered EM magnetic
effect of a current in 1820, based on
Natur Philosophie

↳ Electric motor (, Faraday (1821)
~~Arago~~

Reverse effect of electromagnetic induction
discovered by Faraday in 1831 (
Change in magnetic field is required)

Faraday introduced theory of electrotonic state (stress thro' a system of particles) → Force Atoms → lines of which theory proposes Force

1834 Discovered laws of electrolysis

1837 - 1838 Discovered specific inductive capacity effect of dielectric

1845 Discovered Faraday effect
~~Rotation~~ plane polarization rotated by a magnetic field (suggested to Faraday by Kelvin)

~~1846~~ 1845 Discovered diamagnetism
(although it had been observed by Brugmans in 1778)

repulsion of Bi by a magnet ←

- theory of conductibility of magnetic lines of force (reverses Weber's reverse polarity theory) i.e. polarity theory of electrotonic state now quite replaced by 'lines of force' theory.

cp III, pp. 200 et seq.

Faraday's work on gravitation & conversion of forces bears his last serious work.)

Faraday influenced by Coleridge - debt to Boscovich.

a) Did not believe in atoms of matter - only centres of force. (Speculations on...)

b) Force exists as 'lines of force' - element of reality for Faraday

c) No action at a distance - essential effect of the medium, 'later force fields'

d) did not believe in an aether

N.B Sir Wm Heaviside who worked on E, H, and A as the reality of the field.

After 1865 idea of physics based on 2 sets of equations

Matter — another models — Field

Newton — Maxwell

mechanics — E a field

hydrodynamics — other

heat

Actual Model not to reduce field to mechanical action i.e. reduce field to matter

cf Faraday's unified theory, Matter reduces to field

Faraday was no mathematician.
, optical e.g. theory of light
in his 'Thoughts on Ray Vibrations'

Faraday's views contrast with work
of Continental (French) Action at a
distance school represented most
prominently by André Marie Ampère (1775–1836)
and Wilhelm Weber (1804–1891) {and also
Helmholtz}.

Faraday's ideas given a mathematical
model by

Kelvin (in 1845))
and then taken up by

Maxwell in 3 papers.

1856 – On Faraday's Lines of Force – fluid
model.

1861–1862 On Physical Lines of Force – molecular
vortex model

[electrotonic state = Vector potential canonically H as 'real']

1865 On a Dynamical Theory of the Electromagnetic Field
(dispenses with models)

1) Energy located in the field
of 

oscillators $E_e + E_h = const$

of Poynting Vector (1884)

2) Concept of the different aether
— continuous around the [illegible]
discontinuous — aether in a vacuum

↳ e.m. theory of light ( )

E.M. waves detected by

Heinrich Rudolf Herz (1857–1894) in 1886–1888

cf. Herz: Electric Waves.

2nd half of 19th century elaborate aether models + vortex theory of atoms (Kelvin, J.J. Thomson (not [illegible]))
↳ reduces all matter to aether

Attempts to detect motion relative to the aether:

Aether-dragging Fresnel — verified by Fizeau and ~~Foucault~~ Airy (water filled telescope no effect on aberration)
(1851) (1871)

Stationary aether + electron theory of H.A. Lorentz (1853–1928)

Michelson – Morley Experiment (1887)

↳ Lorentz–Fitzgerald Contraction (1892)

↳ Special Relativity (1905)

But note Albert Einstein (1879–1955) did not abolish the aether — of 'substantial' idea of space-time in G.R. Matter is defined in terms of space-time (perturbation?) also e.m. fields as additional geometrical structure (H. Weyl 1918).

↳ Geometrization of physics (Geometrodynamics)

But relativity denies instantaneous action at a distance — all effects transmitted with finite speed (either as particles or as disturbance of the field)

James Clerk Maxwell (1831 – 1879)

b. Edinburgh / 1st mathematical paper at age of 14. 1850 went up to Cambridge

2nd Wrangler, Joint Smith's Prizeman (with E. J. Routh). Taught at Aberdeen, King's College London. Appointed 1st Cavendish Professor at Cambridge in 1871.

Main Contributions

1.) Electromagnetic theory
2.) K.T. Gases
3.) Theory of Colour vision
4.) theory Saturn's rings
5.) thermodynamics
6.) Geometrical optics. etc

Joint ed. with T.H. Huxley of 9th ed. of Enc. Britannica.

Rep! Books 1870 Theory of Heat (thermodynamic relations & Maxwell's demon)

1873 Treatise of Electricity & Magnetism

1881 (posthumous) Elementary Treatise on Electricity.

1879 The Unpublished electrical Writings of Hon. Henry Cavendish

Life of Maxwell by L. Campbell & W. Garnett (1882)

Recent life by C.W.F. Everitt (who also wrote entry in Dic. Sci. Biog.)